3

Evaluation of Impacts

3. EVALUATION OF IMPACTS

Chapter 2 discusses repository design evolution and different repository operating modes. This chapter presents the results of the evaluation the U.S. Department of Energy (DOE, or the Department) conducted to estimate the environmental impacts in comparison to those described in Chapter 4 of the *Draft Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DOE 1999). Chapter 4 of the Draft EIS describes short-term (before closure) impacts of the proposed repository on 13 environmental resource areas (land use, air quality, etc.). This Supplement to the Draft EIS discusses the same areas plus transportation of nonradioactive materials, offsite manufacturing, and long-term repository performance associated with the S&ER flexible design (see Chapters 6, 4, and 5 of the Draft EIS, respectively).

As part of its evaluation, DOE selected primary impact indicators in each environmental resource area and in several other areas. *Primary impact indicators* are the most important contributors or parameters used to determine the specific impacts in an environmental resource area. They are directly proportional to the specific impact, and are generally determined during an intermediate step in the impact calculation or evaluation. In some environmental resource areas—for example, those that looked at highest annual impacts—DOE selected primary impact indicators to limit evaluation to a single project phase, the phase that would result in the highest impacts. This focus on situations that could result in the highest possible impacts enables a more concise presentation of the potential impacts. The Department used the ratio of primary impact indicators to specific impacts in the Draft EIS to determine the Supplement impact estimates. Tables in the following sections list the various primary impact indicators and their values for the Draft EIS thermal load scenarios and the S&ER flexible design. The text of these sections presents estimates of specific impacts. The use of primary impact indicators enables a comparison between the impacts of the S&ER flexible design and those presented in the Draft EIS. Table 3-1 lists primary impact indicators. In general, values for the thermal load scenarios are from Chapter 4 of the Draft EIS (DOE 1999) or from the supporting appendixes.

PRIMARY IMPACT INDICATORS

Primary impact indicators are the most important contributors or parameters used to determine the impacts in a particular environmental resource area. By determining a value for a primary impact indicator in a new or developing case—the S&ER flexible design—and comparing it to the same indicator in a completed environmental analysis case—a thermal load scenario from the Draft EIS—DOE can estimate the potential environmental impacts of the new case.

DOE used primary impact indicators in this Supplement to focus on environmental resource areas that under the S&ER flexible design would most likely be affected by evolution of the thermal load scenarios evaluated in the Draft EIS. This Supplement mainly discusses indicators resulting from design enhancements, and includes estimates of changes to their associated environmental impacts.

As discussed in Chapter 2, the lower-temperature repository operating mode would enable the achievement of the target thermal management goals by varying the three primary operational parameters. Section 2.2.2.2.2 provides the ranges being considered for each of these parameters. Operation of the repository within the ranges of these parameters, considering their interrelationships, would achieve the lower-temperature mode. Section 2.1.5.2 of the *Yucca Mountain Science and Engineering Report: Technical Information Supporting Site Recommendation Consideration* (DOE 2001a) provides a set of sample operating scenarios, each of which would be low temperature, that exhibit the inherent design flexibility. To evaluate the environmental impacts of the lower-temperature mode, DOE maximized each of the three primary operational parameters in turn, while assigning the remaining two parameters with

Table 3-1. Primary impact indicators for the Draft EIS design and the S&ER flexible design.[a]

Primary impact indicators[b]	Draft EIS thermal load scenario[c]			S&ER flexible design operating mode	
	High	Intermediate	Low	Higher-temperature	Lower-temperature
Short-term environmental resource areas					
Air quality					
Radon release (curies)	110,000	130,000	340,000	170,000	390,000 to 800,000
Particulate matter (kilograms/year) (construction phase)	170,000	180,000	170,000	220,000	250,000 to 380,000
Gaseous pollutants (nitrogen dioxide, kilograms/year) (operations and monitoring phase)	130,000	130,000	230,000	87,000	88,000 to 96,000
Hydrology					
Water use (acre-feet/year) operations and monitoring phase	250	260	480	230	240 to 360
Total disturbed area (square kilometers)	3.3	3.5	3.5	4.3	4.9 to 8.1
Biological and cultural resources					
Newly disturbed area (square kilometers)	1.8	2.0	2.0	2.8	3.4 to 6.6
Socioeconomics					
Direct workforce (worker-years through 2033)	47,000	47,000	47,000	49,000	50,000 to 53,000
Occupational health and safety					
Total worker-years	63,000	63,000	67,000	68,000	77,000 to 98,000
Exposed worker-years[d]	38,000	39,000	41,000	40,000	46,000 to 56,000
Accidents					
Maximum exposed individual dose (rem)	0.032	0.032	0.032	0.025	0.025
Exposed population dose (person-rem)	14	14	14	11	11
Utilities, energy, and materials					
Electricity use (gigawatt-hours)	5,900	6,700	9,400	11,000	24,000 to 32,000
Peak electrical demand (megawatts)	41	41	41	47	47 to 57
Fossil fuel (million liters)	300	320	390	390	420 to 620
Concrete (thousand cubic meters)	800	920	2,100	660	820 to 1,700
Steel (thousand metric tons)	210	270	810	160	210 to 310
Copper (thousand metric tons)	0.2	0.2	1.0	0.2	0.3 to 0.5
Repository-generated waste and hazardous material					
Construction and demolition debris (cubic meters)	150,000	150,000	150,000	220,000	220,000 to 810,000
Hazardous material (cubic meters)	7,700	7,700	7,700	8,400	8,400 to 15,000
Sanitary and industrial solid waste (cubic meters)	85,000	85,000	110,000	100,000	110,000 to 190,000
Sanitary sewage (million liters)	2,000	2,000	2,200	2,000	2,300 to 4,100
Industrial wastewater (million liters)	980	1,000	1,600	1,000	1,900 to 3,400
Low-level radioactive waste (cubic meters)	71,000	71,000	71,000	71,000	71,000 to 73,000
Other areas					
Transportation					
Transportation of nonradioactive materials (million kilometers)	100	110	140	100	130 to 190
Transportation of construction and operations workers (million kilometers)	360 to 430	380 to 450	360 to 440	470	540 to 680
Long-term performance					
10,000-year peak of the mean annual dose[e] (millirem/year)	0.22	0.13	0.059	0 (zero)[f]	0 (zero)[f]
Peak of the mean annual dose (post-10,000 years)[e] (millirem/year)	260	170	160	120	120[g]
Time at peak[e] (years after closure)	340,000	800,000	800,000	550,000	550,000[g]
Offsite manufacturing					
Titanium (thousand metric tons)	NA[h]	NA	NA	43	43 to 60

a. Values rounded to two significant figures.
b. Section 3.1 discusses each primary impact indicator individually.
c. If the reported values differ between packaging scenarios used in the Draft EIS, the reported values are for the uncanistered packaging scenario.
d. Workers likely to be exposed to radiation during work hours. See Section 3.1.7.
e. Postclosure receptor dose at 20 kilometers (12 miles).
f. Does not include igneous events or human intrusion. The evaluation of such events is independent of repository design evolution.
g. Assumed from higher-temperature case given that thermal differences effectively cease many years before first waste package failure.
h. NA = not applicable.

the corresponding proportional values that enabled meeting the lower-temperature operating mode criteria. The Department expressed the environmental impact results of this evaluation as a range, dependent on the particular operating parameter maximized for the analysis. DOE expects that the environmental impacts for the lower-temperature mode would fall somewhere within the ranges presented for all areas evaluated.

Section 3.1 discusses the evaluation of primary impact indicators and short-term environmental impacts for the environmental resource areas as they would occur with implementation of the S&ER flexible design and compares them to those in the Draft EIS. This section includes the evaluation of impacts from the shipment of nonradiological materials and offsite manufacturing as they relate to current design and operational modes. Section 3.2 discusses improvements in the performance assessment model and the effects of the current design on long-term peak doses. It also presents the comparable values from the Draft EIS. Section 3.3 provides a general perspective on the expected effects on the cumulative impacts presented in the Draft EIS.

3.1 Short-Term Impacts

This section discusses the primary impact indicators and short-term environmental impacts for the higher-temperature and lower-temperature repository operating modes of the S&ER flexible design, and presents the values for the Draft EIS thermal load scenarios in affected environmental resource areas for comparison purposes.

3.1.1 LAND USE AND OWNERSHIP

The S&ER flexible design would result in no changes to land use and ownership from those presented in the Draft EIS (DOE 1999, pp. 4-4 to 4-6). DOE would continue to maintain the current administrative land withdrawal, current right-of-way reservations, and the existing management agreements until Congress approved a permanent land withdrawal. DOE would obtain permanent control of the land surrounding the repository site. An area of approximately 600 square kilometers (150,000 acres) of Bureau of Land Management, U.S. Air Force, and DOE lands in southern Nevada would be sufficient (DOE 1999, p. 4-5). As necessary, DOE would clear land for repository and surface facility construction. The Department does not expect conflict with uses on surrounding lands because repository operations would occur in a confined, secure area over which it would have permanent control. This is existing Federal property, much of which DOE has used for site characterization for nearly two decades.

3.1.2 AIR QUALITY

DOE evaluated primary impact indicators in the areas of radiological and nonradiological air quality from releases of radionuclides and selected criteria pollutants, respectively, to the atmosphere prior to repository closure.

3.1.2.1 Radiological Air Quality

DOE evaluated the total activity of naturally occurring radon and radon decay products released from the repository over the lifetime of the project as the primary impact indicator of radiological air quality. In the Draft EIS analyses, exposure to radon and its decay products accounts for more than 99 percent of the potential radiation dose to members of the public (DOE 1999, p. 4-59).

Table 3-2 lists the total release of radon and its decay products for both the Draft EIS design and S&ER flexible design scenarios.

Table 3-2. Primary impact indicators for air quality.[a]

Primary impact indicators	Draft EIS thermal load scenario[b]			S&ER flexible design operating mode	
	High	Intermediate	Low	Higher-temperature	Lower-temperature
Radon release (curies)[c]	110,000	130,000	340,000	170,000	390,000 to 800,000
Particulate matter (kilograms/year)[d]	170,000	180,000	170,000	220,000	250,000 to 380,000
Gaseous pollutants (nitrogen dioxide, kilograms/year)[e]	130,000	130,000	230,000	87,000	88,000 to 96,000

a. Values rounded to two significant figures.
b. Sources: Radon, DOE 1999, Table G-48; particulate matter, DOE 1999, Tables G-5, G-7, G-10, G-13, G-17, and G-20; gaseous pollutants, DOE 1999, Tables G-19 (values doubled to account for two boilers during operations; see Section G.1.5.5) and G-26.
c. Radon release over the duration of the project through repository closure.
d. Construction phase, when releases would be highest.
e. Operation and monitoring phase, when releases would be highest.

In general, annual average radon releases would be higher for the S&ER flexible design than for the thermal load scenarios presented in the Draft EIS. For the S&ER flexible design, DOE used updated information on radon flux (picocuries per square meter of exposed rock surface per second) and the relationship of radon fluxes to ventilation flow rates in the repository (CRWMS M&O 2000d, all) to develop estimated releases of radon and its decay products from the repository. Higher ventilation flow rates for the S&ER flexible design would result in greater flux of naturally occurring radon from the surrounding rock into the repository. In addition, the project duration for the S&ER flexible design would be longer, ranging from 115 years (5 years for construction, 100 years for operation and monitoring, and 10 years for closure) to 341 years (5 years for construction, 324 years for operation and monitoring, and 12 years for closure), compared to 111 years to 120 years for the Draft EIS thermal load scenarios, enabling radon release from repository ventilation to occur over a longer period. The highest total radon release would result from the combination of the largest repository (with the largest exposed rock internal surface area and, thus, radon flux) and longest preclosure period.

In the Draft EIS design, the highest annual dose to the maximally exposed individual would range from 0.8 to 1.8 millirem. Estimated health impacts to the public over the duration of the project through repository closure from release of radon and its decay products would range from 0.14 to 0.41 latent cancer fatality for the three thermal load scenarios (DOE 1999, p. 4-59). To estimate the potential health impacts of the S&ER flexible design, DOE used the same relationship between radon releases and latent cancer fatalities it used in the Draft EIS. For the higher-temperature repository operating mode, the highest annual dose to the maximally exposed individual would be 1.2 millirem. The higher-temperature mode would result in an estimated 0.22 latent cancer fatality over the lifetime of the project. For the lower-temperature repository operating mode, the highest annual dose to the maximally exposed individual would range from 1.7 to 2.6 millirem. The lower-temperature mode would result in a range from 0.49 to 1.0 latent cancer fatality, depending on the amount of radon released, as listed in Table 3-2.

The use of natural ventilation rather than forced-air ventilation for some portion of the preclosure period would result in less than half of the radon released to the offsite public for that portion of the period.

3.1.2.2 Nonradiological Air Quality

DOE evaluated nonradiological air quality by looking at annual releases of selected criteria pollutants. Under the Draft EIS analysis, releases of fugitive dust during the construction phase would result in concentrations of particulate matter with an aerodynamic diameter of 10 micrometers or less (PM_{10}) that would be the highest percentage of the applicable standard of any criteria pollutant (DOE 1999, Table 4-1). Concentrations of gaseous pollutants (nitrogen dioxide, carbon monoxide, sulfur dioxide) would be highest during the operation and monitoring phase, and annual average concentrations of nitrogen dioxide would be the highest of the gaseous pollutants analyzed in the Draft EIS (DOE 1999, p. 4-12), ranging from 0.46 to 0.83 percent of the regulatory limit. Because all gaseous pollutants would be a very small fraction of the limit, and because the relative differences in all gaseous pollutants would be the same, DOE evaluated releases of nitrogen dioxide as representative of the other gaseous pollutants.

Particulate Matter. Fugitive dust release estimates are a conservative representation of PM_{10} releases, because only a fraction of fugitive dust would have an aerodynamic diameter of 10 micrometers or less. The S&ER flexible design would have greater annual releases of fugitive dust during the construction phase than any of the Draft EIS thermal load scenarios listed in Table 3-2. These increases would result mainly from increased areas of surface land disturbance and the operation of a second concrete batch plant in the North Portal Operations Area (the Draft EIS analyzed only one batch plant, at the South Portal).

In the Draft EIS, the highest percentage of the annual regulatory limit for particulate matter releases during construction was 1.4 percent (DOE 1999, Table 4-1, p. 4-8). The releases for the S&ER flexible design would result in higher air concentrations but would still be small fractions of the applicable PM_{10} air quality standard. The higher-temperature repository operating mode would result in annual fugitive dust concentrations potentially reaching 1.7 percent of the PM_{10} limit. The lower-temperature repository operating mode would have estimated annual fugitive dust concentrations ranging from 1.9 to 2.9 percent of the regulatory limit. The highest concentration would be associated with the additional land disturbance needed for construction of the proposed surface aging facilities.

Gaseous Pollutants. Releases of gaseous pollutants during the operation and monitoring phase—specifically examined for nitrogen dioxide as described above—would be lower for the S&ER flexible design than for the Draft EIS thermal load scenarios. The decreases in gaseous emissions would be due in part to the fact that only one boiler would be operating (at the North Portal Operations Area) under the S&ER flexible design, although this boiler would have 40 percent higher emissions than the previous design. The Draft EIS thermal load scenarios included two boilers (one each in the North and South Portal Operations Areas). DOE eliminated the South Portal boiler, which it would have used to cure concrete for the repository, from the S&ER flexible design. Less concrete would be used in the repository because emplacement drifts would not be lined. In addition, because the excavated rock pile would generally be smaller under the S&ER flexible design—especially in comparison to the low thermal load scenario—the amount of fuel consumed and gaseous emissions for rock pile maintenance would be less.

In the Draft EIS, the highest percentage of the annual regulatory limit for nitrogen dioxide during the operation and monitoring phase was 0.83 percent (DOE 1999, Table 4-3, p. 4-12). The S&ER flexible design higher-temperature repository operating mode would result in annual nitrogen dioxide concentrations potentially reaching 0.31 percent of the regulatory limit. The lower-temperature repository operating mode would have estimated nitrogen dioxide concentrations ranging from 0.31 to 0.34 percent of the regulatory limit. Air concentrations and percentages of regulatory limits for other gaseous pollutants would be similarly reduced for the S&ER flexible design.

3.1.3 HYDROLOGY

The primary impact indicators for hydrology are annual water use and disturbed surface area. Annual water use is a measure of the potential effect on groundwater supplies, and total land area disturbed is a measure of the potential impact from surface-water runoff and infiltration. The Draft EIS discussed other indicators, including such concerns as discharges of water and the presence (and potential release) of contaminants through the completion of the closure phase. Potential impacts associated with these indicators would be minor, and changes in their quantity or potential for impacts under the S&ER flexible design parameters would be unlikely. Table 3-3 lists values for the primary impact indicators being evaluated.

Table 3-3. Primary impact indicators for hydrology.[a]

Primary impact indicators	Draft EIS thermal load scenario[b]			S&ER flexible design operating mode[c]	
	High	Intermediate	Low	Higher-temperature	Lower-temperature
Water use (acre-feet/year)[d]	250	260	480	230	240 to 360
Total disturbed area (square kilometers)	3.3	3.5	3.5	4.3	4.9 to 8.1

a. Values rounded to two significant figures.
b. Sources: Water use: DOE 1999, p. 4-27; total disturbed area: DOE 1999, p. 2-11 and pp. 2-16 to 2-23.
c. Sources: Water use: CRWMS M&O 2000c, Tables 6-9 and 6-16; CRWMS M&O 2000b, Table 6-2; McKenzie 2000, Option 1, Tables 1-9 and 1-16. Total disturbed area: CRWMS M&O 2000b, Table 6-2; CRWMS M&O 2000c, p. 4-9 and Figures 4-4 and 4-6; McKenzie 2000, Option 1, p. 24; Mattsson 2000, p. 21; derived from Griffith 2001, p. 8.
d. Operation and monitoring phase, when use would be highest.

3.1.3.1 Water Use

Annual water demand would be highest during the emplacement and development activities of the operation and monitoring phase. The estimated annual water demand for the higher-temperature repository operating mode would be less than the corresponding estimates for the thermal load scenarios in the Draft EIS. The reduced use of concrete and decreased subsurface excavation (with less need for water for dust suppression) would more than offset the increased demand due to construction of the solar power generating facility and ongoing dust suppression. There would be decreased water demand for the other project phases with the exception of the initial 3-year (CRWMS M&O 2000b, p. 53) surface facility decontamination period at the start of postclosure monitoring activities when decontamination of fuel inventory pools would require more water. The estimated annual water demand would be about 10 percent higher during these years (CRWMS M&O 2000b, Table 6-4; CRWMS M&O 2000c, Table 6-19). Water demand for each of the project phases would be less than the lowest estimates of perennial yield of the hydrographic area [580 acre-feet (720,000 cubic meters)] from which DOE would withdraw the water (DOE 1999, p. 4-29). *Perennial yield* is the amount of water that can be withdrawn annually without depleting the groundwater reserve, specifically for the Jackass Flats groundwater basin. Even adding these quantities to the ongoing Nevada Test Site water demand [280 acre-feet (350,000 cubic meters) per year] (DOE 1999, p. 4-28), withdrawals from this area for the higher-temperature mode would not exceed the lowest estimates of perennial yield.

For the lower-temperature repository operating mode, two variables with the potential to change water-use requirements would be repository size and surface aging. All options of the lower-temperature mode would have larger repository volumes and more subsurface excavation (McKenzie 2000, Option 1, Tables 1-4 and 1-11, and Option 2, Tables 1-4 and 1-11) than the higher-temperature repository operating mode (CRWMS M&O 2000c, Tables 6-4 and 6-11), but less than the Draft EIS low thermal load scenario (CRWMS M&O 1999c, Tables 6.1.1.4-1 and 6.1.2.4-1). More subsurface excavation would require increased water demand to support tunnel boring operations. Accordingly, annual water demand during emplacement and development activities for the lower-temperature mode would be higher than that for the higher-temperature mode, but lower than that for the Draft EIS low thermal load.

For the lower-temperature repository operating mode, the ability to age the waste prior to its placement in the repository would require the construction of a surface aging facility. This facility would involve water demands not included in the higher-temperature repository operating mode. Water demand for the phased construction effort, which would include significant amounts of concrete work, would be about 77 acre-feet (95,000 cubic meters) per year. However, because construction of a surface aging facility would not begin until about 2010, the analysis included the associated water demand with the operation and monitoring phase for the rest of the project, as listed in Table 3-3. There would be no water-intensive activities necessary to support surface aging facility operations. The low end of the annual water demand range listed in Table 3-3 for the lower-temperature mode is associated with the smallest repository under consideration and no surface aging facility. In contrast, the high end of the range represents the largest repository under consideration and the construction of a surface aging facility. Without construction of a surface aging facility, the range of water demand for lower-temperature operations, combined with the ongoing Nevada Test Site water demand, would be below the lowest estimates of perennial yield for the hydrographic area. With construction of a surface aging facility and including ongoing Nevada Test Site water demand, lower-temperature operations would exceed low-end estimates of perennial yield by as much as 10 percent. This would occur during the 12 years the surface aging facility was under phased construction. However, the largest combined water demand (largest repository, construction of a surface aging facility, and the Nevada Test Site water demand) would represent only 16 percent of the highest estimates of perennial yield [4,000 acre-feet (4.9 million cubic meters)] for this hydrographic area (DOE 1999, p. 4-29). Annual water demand for other phases of the project would be very similar to those projected for the higher-temperature mode.

3.1.3.2 Land Area Disturbed

Land disturbance is associated with the potential to change both runoff and infiltration rates, and drainage and erosion patterns. The higher-temperature repository operating mode would result in an additional 0.8 square kilometer (200 acres) of land disturbance (CRWMS M&O 2000b, Table 6-2; CRWMS M&O 2000c, p. 4-9 and Figures 4-4 and 4-6) compared to that described in the Draft EIS (DOE 1999, Table 4-11). This difference includes the 0.24 square kilometer (60 acres) required for the solar power generating facility [based on estimates of land disturbance in Griffith (2001, p. 8) with a 10-percent increase for conservatism]. The rest of the land disturbance [0.6 square kilometer (150 acres)] would be due to increasing the number of ventilation shafts and surface stations from two in the high and intermediate thermal load scenarios to seven in the higher-temperature mode. The surface stations for fans and equipment would require only an estimated 0.03 square kilometer (7 acres) each (CRWMS M&O 2000c, Figures 4-4 and 4-6); the rest of the difference in disturbed area would be attributed primarily to the access roads that would have to be constructed to each station (CRWMS M&O 2000c, p. 4-9). The additional land disturbance would have associated design and engineering controls to minimize impacts to drainage channels, potential for increased erosion, and impacts from flash flooding.

The lower-temperature repository operating mode would require more subsurface excavation than the higher-temperature repository operating mode, resulting in increased land disturbance to support a larger excavated rock storage pile. The disturbed surface area associated with the excavated rock storage pile would range from about 30 to 60 percent higher than that needed for the higher-temperature mode. Including a surface aging facility would increase the disturbed area by as much as 2.4 square kilometers (600 acres) (Mattsson 2000, p. 21). About half of the area disturbed by the surface aging facility could eventually be covered by impermeable surfaces in the form of access roads, buildings and, as the largest contributor, about 0.8 square kilometer (200 acres) of concrete pads for the aging of commercial spent nuclear fuel (Mattsson 2000, p. 21). The disturbed surfaces, particularly those that would be covered with impermeable surfaces, would have impacts on stormwater runoff and infiltration and possibly on groundwater recharge in areas where the runoff was channeled. As with the higher-temperature mode, the additional land disturbance would have associated engineered controls to minimize impacts.

3.1.4 BIOLOGICAL RESOURCES

DOE evaluated the land area that would be disturbed during repository activities to gauge potential impacts to biological resources. As indicated in the Draft EIS, the primary source of potential short-term impacts to biological resources would be related to habitat loss or modification during facility construction and operations associated with the repository. Unlike hydrology, only the newly disturbed or to-be-disturbed land area would be of concern, because these would be areas where undisturbed biological resources could exist. As listed in Table 3-4, the higher-temperature repository operating mode would disturb about 0.8 square kilometer (200 acres) more land area than the Draft EIS thermal load scenarios. Land disturbance for the lower-temperature repository operating mode would be greater than

Table 3-4. Primary impact indicator for biological and cultural resources.[a]

Primary impact indicators	Draft EIS thermal load scenario[b]			S&ER flexible design operating mode	
	High	Intermediate	Low	Higher-temperature	Lower-temperature
Newly disturbed area (square kilometers)[c]	1.8	2	2	2.8	3.4 to 6.6

a. Values rounded to two significant figures.
b. Source: DOE 1999, Table 4-11.
c. To convert square kilometers to acres, multiply by 247.1.

that for the higher-temperature mode—as much as 6.6 square kilometers (1,600 acres) if DOE was to build and operate a surface aging facility.

The Draft EIS reported that the overall impacts to biological resources would be very small (DOE 1999, p. 4-29). Even though the amount of newly disturbed area would increase under the S&ER flexible design, the estimated impacts would still be very small because the biological resources in the Yucca Mountain region include species typical of the Mojave and Great Basin Deserts and generally common throughout those areas. Neither the removal of vegetation from the small area required for the repository nor the very small impacts to some species would affect the regional biodiversity and ecosystem function. The incremental disturbance of land associated with solar power generation would be about 0.24 square kilometer (60 acres). DOE would treat this as an operational area and would control vegetation to minimize potential interference with the solar power generating system. DOE does not expect significant impacts in the vicinity of the solar power generating system associated with changes in surface temperatures or the amount of water reaching the ground, including the potential for the introduction of non-native species.

The increase in land disturbance under the S&ER flexible design would cause additional loss of desert tortoise habitat and could cause the loss of a few more tortoises than the Draft EIS design. The disturbance would involve a very small percentage of the habitat in the region, and the population density of desert tortoises in the area is low in comparison to other parts of the range for this species. DOE anticipates that human activities at the site could directly affect individual tortoises, but does not expect the loss or displacement of these individuals to affect the continued survival of the species.

Heat released to the environment through venting of the repository or associated with an aging facility, if there was one, could influence the local microclimate in the immediate vicinity of the release point. Some animals could be attracted to warmer areas, particularly during periods of cold weather. The total heat removed at the peak—occurring between 10 and 15 years after completion of emplacement—would be about 40 megawatts-thermal (CRWMS M&O 2000c, pp. A-24 and B-2). In comparison, a typical fossil-fuel powerplant with a generating capacity of 1,000 megawatts-electric and 35 percent efficiency (Baird 2001) would release nearly 2,000 megawatts-thermal. Thus, heat released from Yucca Mountain at its peak would be less than 15 percent of that released from a single 1,000-megawatt-electric generating station. In addition, hundreds of thousand of megawatts of capacity reside with nonutilities, not to mention heat releases from commercial, residential, and transportation sources. Thus, measurable local, regional, or global impacts from heat released from the Yucca Mountain Repository would be unlikely.

Heat from the repository should disperse rapidly in the atmosphere, and any influences on plants or animals would be extremely localized and confined to the immediate vicinity of the heat source. As a consequence, heat vented from the repository would be unlikely to affect biological resources locally or globally.

3.1.5 CULTURAL RESOURCES

DOE evaluated the land area that would be disturbed during repository activities to gauge potential impacts to cultural resources. As listed in Table 3-4, the higher-temperature repository operating mode would disturb about 0.8 square kilometer (200 acres) more land area than the Draft EIS thermal load scenarios. Land disturbance for the lower-temperature repository operating mode would be greater than that for the higher-temperature mode, as much as 3.8 square kilometers (940 acres) greater [or 6.6 square kilometers (1,600 acres) total] if DOE was to build and operate a surface aging facility that could be part of this operating mode.

The Draft EIS determined that potential impacts to cultural resources could occur in areas where ground-disturbing activities would take place (DOE 1999, p. 4-37). Increases in both surface activities and numbers of workers at the repository site could increase the potential for indirect impacts at archaeological sites near repository surface facilities. Human activities and increased access could result in harmful effects, both intentional and unintentional, to these fragile resources.

Several known archaeological sites in the vicinity of Midway Valley could be affected by ground-disturbing activities associated with the construction of the surface aging facility (see Figure 2-4 for location). An archaeological site occupies much of Midway Valley, including the general location of the proposed surface aging facility. This site was partially mitigated during site characterization activities in 1991 (Buck, Amick, and Hartwell 1994, all). In addition, intensive mitigation efforts were conducted at a nearby archaeological site in 1993, yielding nearly 25,000 artifacts (Buck et al. 1998, all). Other known archaeological sites occur in the vicinity of the possible location of the solar power generating facility. These sites have not been evaluated beyond field recording, some having been identified more than 20 years ago. One or more of these sites could be affected by construction at the primary location for the solar power generating facility, as well as such features as access roads and transmission cables. Based on the 1988 cultural resources Programmatic Agreement between DOE, the Advisory Council on Historic Preservation, and the Nevada State Historic Preservation Officer (DOE 1988, all), each of these archaeological sites is potentially eligible for listing on the *National Register of Historic Places*, although formal evaluations have not been completed. Possible impacts to these potentially significant resources cannot be fully delineated until the precise areas of ground disturbance are identified and the presence or absence of important cultural features or artifacts can be assessed for the disturbance areas. If important cultural resources are present in or adjacent to the areas to be disturbed by construction activities, DOE would develop and implement a mitigation plan to reduce adverse effects to the resources.

3.1.6 SOCIOECONOMICS

The primary parameter that influences changes to socioeconomic characteristics of the region of influence would be the direct workforce associated with repository activities. Table 3-5 lists the direct workforce as the total number of worker-years from the beginning of construction in 2005 through the end of operations in 2033 (DOE 1999, Table F-1). Socioeconomic analyses are limited to about 30 years because assumptions and estimated impacts beyond that period become too speculative. For the higher-temperature repository operating mode, DOE expects a 2,000-worker-year increase over the thermal load scenarios presented in the Draft EIS. This increase would be due mainly to more workers in surface facilities at the North Portal Operations Area supporting fuel blending operations (see Section 3.1.7). For the lower-temperature repository operating mode, the direct workforce would be larger, with 3,000 to 6,000 more total worker-years required to implement the action than for the thermal load scenarios. The largest number of worker-years would be required if DOE built and operated a surface aging facility.

Table 3-5. Primary impact indicator for socioeconomics.[a]

	Draft EIS thermal load scenario[b]			S&ER flexible design operating mode	
Primary impact indicators	High	Intermediate	Low	Higher-temperature	Lower-temperature
Direct workforce (worker-years through 2033)	47,000	47,000	47,000	49,000	50,000 to 53,000

a. Values rounded to two significant figures.

b. Source: DOE 1999, Table F-1. Worker-years through the end of operations.

The direct workforce affects indirect employment, changes in population, personal income, gross regional product, state and local spending, housing, and public services. The Draft EIS noted that potential incremental impacts in all of these areas would be small or would not change when comparing the projected baseline to the incremental increases generated by the maximum employment case (the combination of scenarios that could produce the highest incremental change in employment, and thus have the greatest potential to affect the socioeconomic environment). Employment and population changes in the region of influence would not exceed one-half of 1 percent under the thermal load scenarios of the Draft EIS (DOE 1999, p. 4-39). Direct employment under the S&ER flexible design could increase by as much as 13 percent over the Draft EIS employment levels. However, the absolute level of employment over the 30-year analysis period and the subsequent incremental changes in peak socioeconomic parameters would still be small—about the same as those reported in the Draft EIS, assuming the employment increase would have the same residential distribution as that assumed in the Draft EIS.

3.1.7 OCCUPATIONAL HEALTH AND SAFETY

Estimates of potential health and safety impacts to workers would be proportional to the types and numbers of workers employed. The number of workers would affect both the estimated number of industrial accidents and the potential radiation exposure to the worker population. DOE estimated changes in the number of total worker-years and “radiologically exposed” worker-years for the project duration. Table 3-6 lists the values.

Table 3-6. Primary impact indicators for occupational health and safety.[a]

	Draft EIS thermal load scenario[b]			S&ER flexible design operating mode	
Primary impact indicators	High	Intermediate	Low	Higher-temperature	Lower-temperature
Total worker-years	63,000	63,000	67,000	68,000	77,000 to 98,000
Exposed worker-years	38,000	39,000	41,000	40,000	46,000 to 56,000

a. Values rounded to two significant figures.
b. Source: DOE 1999, Table F-1.

DOE used all workers and, therefore, total worker-years to estimate potential impacts from industrial hazards because a worker in any workplace could be subject to common industrial accidents, although accident rates vary for different types of workers. “Exposed” workers include both radiation workers and some general employees. Radiation workers would be likely to receive radiation doses as a part of their work responsibilities. General employees could also receive some low-level radiation exposure—for example, from exposure to naturally occurring radon or ambient radiation from naturally occurring primordial radionuclides in the repository—even though they were not radiation workers and would not work in radiation areas. DOE used the total number of exposed worker-years to estimate potential impacts from the radiation dose received from this exposure, namely the number of latent cancer fatalities.

Overall, the total worker-years would increase considerably over the Draft EIS low thermal load scenario only for the lower-temperature repository operating mode, which would require 10,000 to 31,000 additional worker-years. There would be relatively small increases in worker-years during the operations period. Most of the increase would occur because of the lengthened monitoring and ventilation period for the lower-temperature mode. Estimated fatalities from industrial accidents would range from 1.8 to 2 for the Draft EIS thermal load scenarios (DOE 1999, p. 4-58). Estimated industrial fatalities would remain about 2 for the higher-temperature repository operating mode and would increase to 2.2 to 2.8 for the lower-temperature mode.

The number of radiation worker-years for the higher-temperature repository operating mode would decrease by 1,000 from the Draft EIS low thermal load scenario. The lower-temperature repository operating mode would require 5,000 to 15,000 more exposed worker-years than the low thermal load scenario. Again, increases would result from the increased duration of the monitoring period for the lower-temperature mode. The estimated number of latent cancer fatalities in the worker population over the project duration would range from 3.7 to 4.3 for the Draft EIS thermal load scenarios (DOE 1999, p. 4-58), would be about 4.2 for the higher-temperature mode, and would increase to 5.1 to 6.9 for the lower-temperature mode.

3.1.8 ACCIDENTS

The S&ER flexible design includes design and operational changes that could influence the impacts from repository accidents. These changes include (1) reduction in the number of waste handling lines in the Waste Handling Building from five to three, (2) increase in spent nuclear fuel pool storage capacity to accommodate blending, and (3) modifications to the waste package design.

As a result of these changes, the categories of accidents to be evaluated have undergone minor revisions. The maximum reasonably foreseeable accident (at least 1 chance in 10 million per year) in the Draft EIS involved seismic collapse of the entire Waste Handling Building with damage to all fuel elements in dry storage in the building. This would also be the maximum accident for the S&ER flexible design. Potential impacts from this accident would be reduced somewhat for the S&ER flexible design because the estimated number of fuel assemblies in the Waste Handling Building damaged by a hypothetical earthquake has been reduced from 375 (DOE 1999, p. H-24) to 294 (Montague 2000, p. 1) and any hypothetical resulting damage would be reduced. Table 3-7 lists the doses to the maximally exposed individual at the site boundary and the exposed population within 80 kilometers (50 miles) of the maximum accident.

Table 3-7. Primary impact indicators for accidents.[a]

	Draft EIS thermal load scenario[b]			S&ER flexible design operating mode	
Primary impact indicators	High	Intermediate	Low	Higher-temperature	Lower-temperature
Maximum exposed individual dose (rem)	0.032	0.032	0.032	0.025	0.025
Maximum population dose (person-rem)	14	14	14	11	11

a. Values rounded to two significant figures.
b. Source: DOE 1999, Table H-8. Based on 95th-percentile meteorological conditions.

DOE selected radiation dose as the primary impact indicator because it can be converted under generally accepted standards to potential human health impacts. For the maximum accident, differences in radiation dose can be determined by the difference in the number of fuel assemblies damaged. In the Draft EIS, the estimated health impacts to the public from the maximum accident were a 0.000016 probability of a latent fatal cancer in the maximally exposed individual and 0.0072 latent cancer fatality in the exposed population (DOE 1999, p. 4-63). DOE used the same basis to estimate potential health impacts for the S&ER flexible design. These estimated impacts would be a 0.000013 probability of a latent fatal cancer in the maximally exposed individual and 0.0056 latent fatal cancer in the exposed population.

3.1.9 NOISE

The S&ER flexible design would result in very small changes to noise impacts from those presented in the Draft EIS (DOE 1999, pp. 4-65 to 4-66). As described in the Draft EIS, repository activities could generate elevated noise levels at the North Portal, South Portal, Emplacement Shaft, and Development Shaft Operations Areas that could affect workers during normal operations. The potential for noise impacts to the public would be very small due to the distances to any publicly accessible areas. DOE expects no large noise impacts to the public or workers.

3.1.10 AESTHETICS

The S&ER flexible design would result in very small changes to aesthetic impacts from those presented in the Draft EIS (DOE 1999, pp. 4-66 to 4-67). The Draft EIS considered the potential of a surface storage facility in Midway Valley as part of a retrieval scenario (DOE 1999, p. 4-108). It did not consider the presence and operation of a solar power generating facility. DOE would site and build a solar power generating facility such that no portion would be visible from publicly accessible areas. Yucca Mountain has visual characteristics fairly common to the region, and the visibility of the repository site from publicly accessible locations is low or nonexistent. The DOE evaluation of the scenic quality of Yucca Mountain, which used Bureau of Land Management methodology, concluded that the appropriate Visual Resource Management class for Yucca Mountain is C, which is the lowest rating. Repository activities would not cause adverse impacts to the aesthetic or visual resources in the region for the general public.

3.1.11 UTILITIES, ENERGY, AND MATERIALS

The use of utilities, energy, and materials would be affected by differences in the S&ER flexible design. These differences are discussed below and the values are listed in Table 3-8. The primary impact indicators are the same parameters DOE used in the Draft EIS to evaluate impacts.

Table 3-8. Primary impact indicators for utilities, energy, and materials.[a]

	Draft EIS thermal load scenario[b]			S&ER flexible design operating mode	
Primary impact indicators	High	Intermediate	Low	Higher-temperature	Lower-temperature
Electric power use (gigawatt-hours)	5,900	6,700	9,400	11,000	24,000 to 32,000
Peak electrical demand (megawatts)	41	41	41	47	47 to 57
Fossil fuel (million liters)	300	320	390	390	420 to 620
Concrete (thousand cubic meters)	800	920	2,100	660	820 to 1,700
Steel (thousand metric tons)	210	270	810	160	210 to 310
Copper (thousand metric tons)	0.2	0.2	1.0	0.2	0.3 to 0.5

a. Values rounded to two significant figures.
b. Source: DOE 1999, Tables 4-10, 4-37, and 4-38.

3.1.11.1 Electric Power

Total electric power use would increase by at least 1,600 gigawatt-hours for the higher-temperature repository operating mode over the Draft EIS thermal load scenarios, mainly due to additional requirements for operating storage pools in the surface facilities (CRWMS M&O 2000b, p. 21) and the repository ventilation fans. During the early stages of the operation and monitoring phase (2010 to 2033), the development of emplacement drifts would continue in parallel with emplacement activities, including the operation of ventilation fans. During this period, the peak electrical demand reported in the Draft EIS would be 41 megawatts (DOE 1999, Table 4-37, p. 4-68) or less, depending on the thermal load and packaging scenarios. For the S&ER flexible design higher-temperature mode, the peak electrical demand could increase by 6 megawatts to 47 megawatts, again due to operating storage pools and ventilation fans. Following the completion of excavation activities, the demand for electric power would drop and would continue to drop following the completion of emplacement. As reported in the Draft EIS, the repository demand for electricity would be well within the expected regional capacity for power generation (DOE 1999, Table 4-37, p. 4-68).

The Draft EIS noted that the estimated repository electric power demand would exceed the current transmission capacity to the site after construction began in 2005 (DOE 1999, pp. 4-70 and 4-71). DOE would have to increase the transmission capacity to the site to accommodate the initial demand of about 24 megawatts during the construction phase and to support the estimated peak demand of as much as 47 megawatts during the operation and monitoring phase. Although DOE is now considering the construction and operation of a 3-megawatt onsite solar power generating facility in conjunction with the proposed repository (Griffith 2001, p. 1), that system would not alleviate the need for upgrading transmission capacity. This solar power generating facility would produce electric power for about 6 hours each day (Griffith 2001, p. 1), and DOE would feed the power produced by the system into the Nevada Test Site power grid from which the repository site draws power.

The lower-temperature repository operating mode would also increase electric power use and peak electrical demand, as listed in Table 3-8. The increased use and demand would be driven by additional ventilation duration, changes in repository size, and aging operations under lower-temperature mode options. The most dominant factor for electric power use would be the ventilation time, which, when extended to 300 years of postemplacement cooling, would substantially increase the total electric power use while the annual use remained essentially unchanged. The Draft EIS identified potential electric power impacts as less than 1 percent of the Nevada Power Company projected peak demand in 2010 (DOE 1999, p. 4-71). This is also the case for the S&ER flexible design. The use of natural ventilation rather than forced-air ventilation for some portion of the preclosure period would result in a substantial decrease in electric power use.

3.1.11.2 Fossil Fuels

Fossil fuels used during the construction, operation and monitoring, and closure of the repository would include diesel fuel and fuel oil. Under the higher-temperature repository operating mode, the consumption of fossil fuels would equal that for the low thermal load scenario for the S&ER flexible design. For the lower-temperature repository operating mode, use could increase by almost 60 percent. The increase would be due primarily to increased surface activity associated with aging and extended monitoring periods. The Draft EIS identified fossil-fuel impacts as less than 5 percent of the 1996 capacity in Clark, Lincoln, and Nye Counties (DOE 1999, p. 4-72). This is also the case for the S&ER flexible design.

3.1.11.3 Construction Material

The primary materials needed to construct the repository would be concrete, steel, and copper. Concrete, which consists of cement and aggregate, would be used for tunnel liners for the main and ventilation drifts in the subsurface and for the construction of the surface facilities. Aggregate for concrete would be developed onsite, and cement would be purchased regionally. Steel would be required for a variety of uses including rebar, piping, ground support, vent ducts, and tracks. The quantities of steel and concrete required for the higher-temperature repository operating mode would be about 20 percent and 31 percent, respectively, of those required for the Draft EIS low thermal load scenario. Slightly more concrete and steel would be used during construction of the storage pools in the Waste Handling Building, but substantially less of these materials would be used for development of the drifts because the total required drift length would be less (CRWMS M&O 2000c, Chapters 4 and 6). If DOE used surface aging in conjunction with the lower-temperature repository operating mode, the amount of concrete and steel used would still be less than the Draft EIS low thermal load. Approximately the same amount of copper would be used for the higher-temperature mode as for the Draft EIS intermediate thermal load. Copper would be used primarily for electrical wiring and equipment. For the lower-temperature mode, longer drifts and additional facilities would result in increased copper use over that for the higher-temperature mode, but the amounts would still be lower than those for the Draft EIS low thermal load scenario. The Draft EIS identified the potential impacts of construction material use (DOE 1999, pp. 4-72 to 4-73). These impacts are not likely to change for the S&ER flexible design.

3.1.12 MANAGEMENT OF REPOSITORY-GENERATED WASTE AND HAZARDOUS MATERIALS

The types of waste generated under the S&ER flexible design would be the same as those described in the Draft EIS and include construction and demolition debris, hazardous waste, sanitary and industrial solid waste, sanitary sewage, industrial wastewater, and low-level radioactive waste. Table 3-9 lists the estimated quantities of generated waste. DOE based the waste estimates for the S&ER flexible design on construction experience, water use estimates, and Yucca Mountain Site Characterization Project experience with wastewater generation from underground dust suppression. These estimates do not include used solar panels because DOE anticipates that recycling options would be available by the time the first solar panels would require replacement, about 2030. Solar panel replacement once every 20 years (Griffith 2001, p. 8) would generate about 350 metric tons (390 tons) of material.

Table 3-9. Primary impact indicators for repository-generated waste.[a]

	Draft EIS thermal load scenario[b]			S&ER flexible design operating mode	
Primary impact indicators	High	Intermediate	Low	Higher-temperature	Lower-temperature
Construction and demolition debris (cubic meters)	150,000	150,000	150,000	220,000	220,000 to 810,000
Hazardous material (cubic meters)	7,700	7,700	7,700	8,400	8,400 to 15,000
Sanitary and industrial solid (cubic meters)	85,000	85,000	110,000	100,000	110,000 to 190,000
Sanitary sewage (million liters)	2,000	2,000	2,200	2,000	2,300 to 4,100
Industrial wastewater (million liters)	980	1,000	1,600	1,000	1,900 to 3,400
Low-level radioactive waste (cubic meters)	71,000	71,000	71,000	71,000	71,000 to 73,000

a. Values rounded to two significant figures.
b. Source: DOE 1999, Table 4-42.

The quantities of each waste type would be affected by design enhancements and operating parameters. The estimated waste quantities generated under the higher-temperature operating mode would not exceed those presented for the Draft EIS low thermal load scenario with the exception of construction and demolition debris and hazardous waste, which are discussed below. The largest waste volumes would result from the lower-temperature repository operating mode if DOE used surface aging. Additional waste would be generated from the construction and demolition of the aging facility and 4,500 dry storage vaults, a potentially longer period of emplacement and aging, and a longer monitoring and maintenance period. DOE does not expect to generate mixed waste. However, repository facilities would also have the capability to package and temporarily store mixed waste that operations could generate in unusual circumstances.

3.1.12.1 Construction and Demolition Debris

The estimated quantities of construction and demolition debris would exceed those for the Draft EIS thermal load scenarios by at least 70,000 cubic meters (2.5 million cubic feet) due to differences in the size and design of surface facilities, mainly the solar power generating facility and four fuel inventory pools (CRWMS M&O 2000b, pp. 48 and 57). About 220,000 cubic meters (7.8 million cubic feet) of construction and demolition debris would be generated under the higher-temperature repository operating mode, and as much as 810,000 cubic meters (29 million cubic feet) under the lower-temperature operating mode. This debris would be disposed of at an onsite landfill designed to accommodate the waste volume. If DOE did not build a landfill at the repository site, it could ship construction and demolition debris to the Nevada Test Site’s Area 10C landfill, which has a disposal capacity of 990,000 cubic meters (35 million cubic feet) (DOE 1996, p. 4-37). This landfill has an estimated 70-year operational life (DOE 1995, pp. 8 and 9). Debris generated under the higher-temperature mode would use about 22 percent of the Nevada Test Site landfill capacity. Disposal of lower-temperature repository construction and demolition debris would use up to 82 percent of the landfill's current capacity, so expansion, as well as service life extension, would be necessary to accommodate both Nevada Test Site and repository debris.

3.1.12.2 Hazardous Waste

Hazardous waste, which would be the same for the Draft EIS design and the S&ER flexible design, would be packaged and shipped off the site for treatment and disposal. DOE could dispose of repository-generated waste in conjunction with the Nevada Test Site, which has contracts with commercial facilities, or it could contract separately with the same or another commercial facility with the appropriate permits and available treatment and disposal capacity. The estimated quantities of hazardous waste generated under the S&ER flexible design would exceed those for the Draft EIS thermal load scenarios by at least 700 cubic meters (25,000 cubic feet) due to differences in the size and design of surface facilities, mainly the solar power generating facility and four fuel inventory pools (CRWMS M&O 2000b, pp. 48 and 57). About 8,400 cubic meters (300,000 cubic feet) of hazardous waste would be generated under the higher-temperature operating mode and as much as 15,000 cubic meters (530,000 cubic feet) under the lower-temperature repository operating mode. The Environmental Protection Agency's National Capacity Assessment Report (EPA 1996, pp. 32, 33, 36, 46, 47, and 50) indicates that the estimated 1993 to 2013 capacity for treatment and disposal of solids and liquids at permitted facilities in the western states (including Nevada and other states to which repository waste could be shipped for treatment and disposal) is about seven times more than the demand for these services. The estimated landfill capacity is about 50 times the demand. Therefore, the impacts from the treatment and disposal of hazardous waste would be small.

3.1.12.3 Sanitary and Industrial Solid Waste

The quantity of sanitary and industrial solid waste generated would vary due to changes in the number of workers and length of the monitoring and closure periods. Repository-generated sanitary and industrial solid waste could be shipped to the Nevada Test Site for disposal in the Area 23 landfill, which has a capacity of 450,000 cubic meters (16 million cubic feet) (DOE 1996, p. 4-37) and an expected operational life of 100 years (DOE 1995, pp. 8 and 9). The S&ER flexible design would generate sanitary and industrial solid waste that would be similar to or nearly double the Draft EIS design. Under the higher-temperature repository operating mode, about 100,000 cubic meters (3.5 million cubic feet) of waste would be generated, using about 22 percent of the landfill capacity. The lower-temperature repository operating mode could generate from 110,000 to 190,000 cubic meters (3.9 to 6.7 million cubic feet) of waste, consuming from 24 to 42 percent of the landfill capacity. For this mode, landfill capacity expansion and service life extension would be necessary.

3.1.12.4 Sanitary Sewage and Industrial Wastewater

About 2 billion liters (530 million gallons) of sanitary sewage would be generated under the higher-temperature repository operating mode and as much as 4.1 billion liters (1.1 billion gallons) under the lower-temperature repository operating mode. About 1 billion liters (260 million gallons) of industrial wastewater would be generated under the higher-temperature mode and as much as 3.4 billion liters (900 million gallons) under the lower-temperature mode. Sanitary sewage and industrial wastewater for the S&ER flexible design would be slightly more than double the amounts for the Draft EIS design. As reported in the Draft EIS, DOE would treat and dispose of sanitary sewage in onsite septic systems and industrial wastewater in onsite evaporation ponds (DOE 1999, p. 4-77).

3.1.12.5 Low-Level Radioactive Waste

The amount of low-level radioactive waste generated under the S&ER flexible design for the higher-temperature repository operating mode would be the same as that for the Draft EIS design. About 71,000 cubic meters (2.5 million cubic feet) of low-level radioactive waste would result from the receipt and packaging of spent nuclear fuel and high-level radioactive waste during the operation and monitoring phase and from decontamination and decommissioning activities during the closure phase. DOE would treat this waste in the Waste Treatment Building. In the lower-temperature repository operating mode cases that involve aging, radiation surveys at the aging facility would generate small additional quantities of low-level radioactive waste. The lower-temperature mode would result in 71,000 to 73,000 cubic meters (2.5 to 2.6 million cubic feet) of low-level radioactive waste. DOE would dispose of this waste at the Nevada Test Site, which accepts low-level radioactive waste for disposal from other DOE sites and has an estimated disposal capacity of 3.15 million cubic meters (110 million cubic feet) (DOE 1998b, p. 2-19). Waste generated under either the higher-temperature or lower-temperature mode would use about 2.3 percent of this capacity.

3.1.13 ENVIRONMENTAL JUSTICE

The Draft EIS analysis determined that activities under any of the three thermal load scenarios would not have disproportionately high and adverse effects on minority or low-income populations. This Supplement considers activities at the repository site that could result in increased ground disturbance and numbers of workers over levels evaluated in the Draft EIS, as well as a possible surface aging facility and a solar power generating facility included in the S&ER flexible design. In most study areas, implementing either the higher-temperature or the lower-temperature repository operating mode would produce impact levels not materially different from the levels described in the Draft EIS. Therefore, for the reasons described in the Draft EIS, the implementation of the S&ER flexible design would not cause disproportionately high and adverse effects on minority or low-income populations.

American Indian Perspectives on the Yucca Mountain Site Characterization Project and the Repository Environmental Impact Statement, prepared by the American Indian Writers Subgroup of the Consolidated Group of Tribes and Organizations, expresses values held by Native Americans living in the region surrounding the proposed repository and describes particular places of cultural importance in the vicinity of the repository (AIWS 1998, pp. 2-13 to 2-15). The Draft EIS contains representative statements of views and beliefs excerpted from that document (DOE 1999, Section 4.1.13.4).

DOE recognizes that it could not construct and operate a repository at Yucca Mountain without some conflict with Native American concerns. DOE will continue to consult with tribal organizations and will work with representatives of the Consolidated Group of Tribes and Organizations to ensure the consideration of tribal rights and concerns before making decisions or implementing programs that could affect tribes. DOE will also continue its protection of Native American sacred sites, cultural resources, and potential traditional cultural properties, and will implement appropriate mitigation measures.

3.1.14 TRANSPORTATION

Transportation is not an environmental resource area, but rather a connected action that could result in environmental impacts.

Transportation of spent nuclear fuel and high-level radioactive waste to the repository would not be affected by the repository design evolution and is not evaluated in this Supplement. However, the S&ER flexible design would have different requirements for system components and construction materials. Transporting these materials and components from the manufacturer or supplier to the repository site could have environmental effects. In addition, the S&ER flexible design would result in different requirements for the transportation of workers.

The primary impact indicator for the evaluation of transportation impacts is the distance over which DOE would transport workers and the required material. Nonradiological environmental impacts, such as the number of trailer-truck and automobile traffic fatalities and the health effects produced by vehicle emissions (including automobile and truck exhaust and fugitive dust), would be proportional to the distance traveled. Table 3-10 lists the distances. The evaluation used the same bases as the evaluation of nonradiological transportation impacts in the Draft EIS, which contains results for transportation of workers and materials for repository construction, operation and monitoring, and closure, including construction materials, supplies, equipment, disposal containers, consumables, office and laboratory supplies, samples, mail, and wastes (DOE 1999, Section J.3.6).

Table 3-10. Primary impact indicators for transportation.[a]

	Draft EIS thermal load scenario			S&ER flexible design operating mode	
Primary impact indicators	High	Intermediate	Low	Higher-temperature	Lower-temperature
Transportation of nonradioactive materials (million kilometers)[b]	100	110	140	100	130 to 190
Transportation of construction and operations workers (million kilometers)	360 to 430	380 to 450	360 to 440	470	540 to 680

a. Values rounded to two significant figures.
b. To convert kilometers to miles, multiply by 0.62137.

The S&ER flexible design would require the transportation of drip shields, emplacement pallets, solar panels, and materials for constructing the solar power generating facility to the repository site. The additional transportation distance for these new items would be more than offset by the reduction in quantity and transportation of concrete and steel in the S&ER flexible design. In addition, only cement would be transported for the S&ER flexible design while the aggregate for concrete would be prepared at the site. This differs from the assumption in the Draft EIS that all materials for concrete would be transported to the site, thereby reducing the number of shipments required.

In the Draft EIS, the transportation of nonradiological materials prior to repository closure would result in an estimated three to four traffic fatalities (DOE 1999, Tables J-62 and J-64). Based on the shorter total transportation distance required for the S&ER flexible design and the relationship between distance traveled and impacts presented in the Draft EIS, DOE estimates three traffic fatalities for the higher-temperature repository operating mode.

The farthest materials transportation distance required for the lower-temperature repository operating mode [190 million kilometers (118 million miles)] would involve a combination of the longest operation and monitoring period with the largest number of disposal containers. This mode could result in an estimated four to six traffic fatalities.

In the Draft EIS, transportation of workers over the life of the project would result in an estimated 3.6 to 4.5 traffic fatalities (DOE 1999, Table J-63). Based on the larger number of worker-years estimated for the higher-temperature repository operating mode, DOE estimates about 4.7 traffic fatalities. The lower-temperature repository operating mode could result in an estimated 5.4 to 6.8 traffic fatalities.

The Draft EIS illustrates that the number of possible fatalities estimated from inhalation of vehicle emissions over the life of the project resulting from the transportation of materials and workers through repository closure would be very small (0.12). Based on the relationship between these impacts and the distance traveled, as presented in the Draft EIS, the expected impacts for the S&ER flexible design would remain very small.

3.1.15 OFFSITE MANUFACTURING

Offsite manufacturing is not an environmental resource area but rather a connected action that could result in environmental impacts. In this Supplement, the comparison to the Draft EIS considers quantities of manufactured components, rather than the amount of material used to manufacture the components.

The S&ER flexible design provides an improved engineered barrier system including more corrosion-resistant materials for the waste packages, individual corrosion-resistant supports for the waste packages, and a titanium canopy over each waste package to serve as a drip shield. These components would be manufactured away from the site, increasing the breadth of potential environmental effects to offsite activities and locations. In addition, the construction of a 3-megawatt solar power generating facility as part of the S&ER flexible design would result in the need for about 27,000 solar panels (Griffith 2001, p. 2) that DOE would buy from offsite manufacturers every 20 years. The surface aging of some commercial spent nuclear fuel at the repository, which is an option under the lower-temperature repository operating mode, would result in the need to buy as many as 4,500 dry storage canister and cask systems from offsite sources.

The evaluation of offsite manufacturing used the same analysis methods as those described in the Draft EIS (DOE 1999, p. 4-86). Table 3-11 lists the quantities of components manufactured away from the site and analyzed for the higher-temperature and lower-temperature repository operating modes and the quantities for the Draft EIS thermal load scenarios.

Table 3-11. Quantities of offsite-manufactured components for the proposed Yucca Mountain Repository.

			S&ER flexible design operating mode	
Component	Description	Draft EIS[a]	Higher-temperature	Lower-temperature
Disposal containers	Containers for disposal of SNF[b] and HLW[b]	10,200 to 11,400	11,300	11,300 to 16,800
Rail shipping casks or overpacks	Storage and shipment of SNF and HLW	0 to 110	0 to 110	0 to 110
Legal-weight truck shipping casks	Storage and shipment of uncanistered fuel	10 to 120	10 to 120	10 to 120
Drip shields	Titanium cover for a waste package	0	10,500	11,300 to 15,000
Emplacement pallets	Support for emplaced waste package	(c)	11,300	11,300 to 16,800
Solar panels[d]	Photovoltaic solar panels – commercial units	0	27,000	27,000
Dry storage canisters[e]	Metal canister for commercial SNF assemblies during aging	0	0	0 to 4,500
Dry storage casks[e]	Concrete and steel dry storage vault for aging	0	0	0 to 4,500

a. Source: DOE 1999, Table 4-44.
b. SNF = spent nuclear fuel; HLW = high-level radioactive waste.
c. The waste package supports evaluated in the Draft EIS were not offsite manufactured components.
d. Number of panels in use at any one time.
e. Necessary only if DOE used the surface aging concept as part of a lower-temperature operating mode.

As currently planned, the disposal containers, shipping casks, and emplacement pallets would be manufactured over 24 years (CRWMS M&O 2000b, Figure 6-1) to support emplacement in the repository for the S&ER flexible design.

The titanium drip shields would not be needed until closure of the repository; therefore, the analysis assumed that delivery of these components to the repository would not begin until 76 to 300 years after the completion of emplacement. The solar power generating facility would be built over a 6-year period beginning in 2005 (Griffith 2001, p. 6).

The dry storage canisters and casks would be needed only if the surface aging concept was used in conjunction with the lower-temperature repository operating mode. Because surface aging would occur in parallel with emplacement, the canisters and casks and the waste packages would be manufactured during the same 24-year period.

The S&ER flexible design waste package would be more complex to manufacture than the Draft EIS design because of the corrosion-resistant materials used and the more complex configuration. Additional components, including the emplacement pallets and titanium drip shields, would primarily involve metal fabrication and would have fewer potential impacts than the waste packages because they would be much less complex to manufacture. DOE anticipates that the additional components would not be manufactured at the same facilities as the waste packages or other components. The factors related to manufacturing shipping casks have not changed from the Draft EIS.

The 27,000 solar panels would be manufactured over a 6-year period. The panels would be commercially available components that DOE could buy from several vendors, so any new types of environmental impacts would be unlikely. They would be replaced about every 20 years over the life of the project.

Concrete dry storage casks, if used for surface aging under the lower-temperature repository operating mode, would be partially fabricated at the repository site. The carbon-steel shell would be manufactured away from the site while the concrete would be placed in the shell on the site. Each shell would be 3.4 meters (11 feet) in diameter by 5.9 meters (19 feet) high and would be made from 1.9 to 13-centimeter (0.75 to 5-inch)-thick carbon-steel plate. The shell would weigh about 25 to 30 metric tons (28 to 33 tons), which is about the same weight as an empty waste package, but it would be fabricated from less expensive carbon steel and manufactured to less demanding procedures and specifications.

The material requirements to manufacture the components for the S&ER flexible design have increased slightly. The titanium for the drip shields is a new material that the Draft EIS did not evaluate. Fabrication of the drip shields would require from 43,000 to 60,000 metric tons (47,000 to 66,000 tons) of titanium, depending on the spacing between waste packages. Titanium is classified as a Federal Strategic and Critical Inventory material, but the annual repository requirement would be less than 8 percent of the current U.S. production capacity (Gambogi 1997, p. 80.7) if the 60,000 metric tons were required over the 10-year period when the drip shields would be manufactured. Titanium is the ninth most common element in the Earth’s crust (U.S. Bureau of Mines 1985, p. 859), but it is somewhat difficult to refine into metal. Because the drip shields would not be needed until repository closure, there would be adequate time to expand production.

The Draft EIS presents the impacts associated with offsite manufacturing of disposal containers and shipping casks for air quality, health and safety, socioeconomics, material use, waste generation, and environmental justice (DOE 1999, Section 4.1.15). The same general conclusions are assumed to apply for the S&ER flexible design, in that impacts would be small. The Final EIS will contain a detailed analysis of the impacts of all offsite manufacturing for the S&ER flexible design.

3.2 Long-Term Impacts

This section summarizes important design enhancements to long-term performance, improvements in the Total System Performance Assessment model since the Draft EIS, and the resulting effects on long-term performance in terms of the mean peak radiation dose to a receptor located 20 kilometers (12 miles) from the repository.

3.2.1 IMPORTANT DESIGN ENHANCEMENTS

Important design enhancements since the publication of the Draft EIS that would affect long-term repository performance are the addition of titanium drip shields over the waste packages and the redesign of the waste packages incorporating an outer layer of Alloy-22. These changes would combine to prolong the period before any initial release of radionuclides from waste packages.

3.2.2 CHANGES TO THE ASSESSMENT MODEL FOR LONG-TERM PERFORMANCE

Table 3-12 lists the basic structure of the Total System Performance Assessment model for the nominal case [*Yucca Mountain Science and Engineering Report: Technical Information Supporting Site Recommendation Consideration* (DOE 2001a, Section 4.4.1)], which is very similar to that used in the Draft EIS (DOE 1999, Chapter 5). The nominal case models repository behavior with no unexpected natural events or human intrusion. One difference is the addition of a subsystem model for the degradation of the drip shield, which was not in the Draft EIS design. The implementation of some of the subsystem models has changed. Table 3-13 summarizes the major changes and their effects on the peak of the mean annual radiation dose to the receptor. The Science and Engineering Report sections listed as references in Table 3-13 contain more details on the models. Subsystem models with very minor changes in implementation are not listed. Most of the subsystem models incorporate updated and more recent data. In particular, they incorporate new data from various underground tests in the repository horizon and data from laboratory tests. The Science and Engineering Report contains more details on new data sets (DOE 2001a, Section 4.2).

Table 3-12. Basic structure of the Total System Performance Assessment model.

Model components	Subsystem model
Unsaturated zone flow	Climate, infiltration, unsaturated zone flow above repository, seepage, coupled processes effects on unsaturated zone flow
Engineered barrier system environment	Mountain scale thermal-hydrologic model, drift scale thermal-hydrologic model, in-drift geochemical model
Waste package and drip shield degradation	Waste package and drip shield degradation model
Waste form degradation	Solubilities, inventory, in-package chemistry, colloid model, cladding degradation model, waste form dissolution model, seismic cladding model
Engineered barrier system transport	Radionuclide transport model, colloid model
Unsaturated zone transport	Unsaturated zone transport model, colloid model
Saturated zone flow and transport	Saturated zone flow and transport model
Biosphere	Soil removal, biosphere dose conversion factor, wellhead dilution

For the integration of the Total System Performance Assessment, the software used for the Draft EIS analysis has been superseded by an updated software package called GoldSim® (a product of Golder Associates under license to DOE). GoldSim® incorporates much the same performance assessment calculational approach, but with substantial improvements in the user interface and data handling.

3.2.3 RESULTS FOR LONG-TERM PERFORMANCE

Analysis of the S&ER flexible design using the new model formulations and updated and improved data sets for many of the model input parameters, as discussed above, produced the following results. During

Table 3-13. Changes to the Total System Performance Assessment model.

Submodel	Change	Estimated effect	Reference[a]
Unsaturated zone flow	Updated climate model	Neutral	4.2.1.1.1
	Added interaction of moisture in fractures and rock matrix	Possible reduction in dose	4.2.1.1.4
	Added perched water models	Neutral	4.2.1.3.1.2
	Flow through unsaturated zone and, therefore, seepage varies with time	More climate sensitivity, possible increase in dose	4.2.1.3.6
	Coupling between thermal, hydrologic, and chemical effects	Possible increase in dose	4.2.2.1.2
Waste package and drip shield degradation	Changes to model new package design and addition of drip shield model	Decrease in dose up to 10,000 years	4.2.4.3
	Experimental corrosion data replacing expert judgment	Decrease in dose up to 10,000 years, increase in peak dose after 10,000 years	4.2.4.3.2
Waste form degradation	More detailed cladding degradation model that includes mechanical failures and localized corrosion	Increase in dose	4.2.6.3.3
	Add comprehensive model of colloid formation effects on radionuclide mobilization	Increase in dose	4.2.6.3.8
	Increased number of radionuclides modeled from 9 to 21	Increase in dose	4.4.1.4
	Neptunium solubility model incorporating secondary phases	Decrease in dose after 10,000 years	4.2.6.3.7
Engineered barrier system transport	New comprehensive model for transport of radionuclides from colloid effects	Increase in dose	4.2.7.4.2
Unsaturated zone transport	New comprehensive model for transport of radionuclides from colloid effects	Increase in dose	4.2.8.4.3
Saturated zone flow and transport	Colloid-facilitated transport in two modes: as an irreversible attachment of radionuclides to colloids, originating from waste, and as an equilibrium attachment of radionuclides to colloids	Increase in dose	4.2.9.4
	Three-dimensional transport model	Neutral	4.2.9.4
	Plume capture method for well concentrations (total radionuclides dissolved in water usage)	Possible decrease in dose	4.2.9.4
Biosphere	Change from MEI in the Draft EIS to “receptor,” with a slightly different definition consistent with proposed EPA and NRC regulations[b]	Neutral	4.2.10.1

a. Section numbers in the *Yucca Mountain Science and Engineering Report: Technical Information Supporting Site Recommendation Consideration* (DOE 2001a).

b. Abbreviations: MEI = maximally exposed individual; EPA = Environmental Protection Agency; NRC = Nuclear Regulatory Commission.

the first 10,000 years after closure, the peak of the mean annual dose to a receptor at 20 kilometers (12 miles) for the Proposed Action inventory and nominal scenario for the higher-temperature repository operating mode would be zero (CRWMS M&O 2000e, Section 4.1.1) because waste packages would remain intact for more than 10,000 years. Doses for the lower-temperature repository operating mode would also be zero for the first 10,000 years because waste packages would remain intact for as long as or longer than for the higher-temperature mode (CRWMS M&O 2000e, Section 4.6.2). The peak of the mean annual dose (post-10,000 years) to the receptor for the Proposed Action inventory and nominal case would be approximately 25 percent less than the dose reported for the low thermal load scenario, which produced the lowest dose of the three thermal loads discussed in the Draft EIS. The peak of the mean dose would occur approximately 550,000 years after repository closure (DOE 2001a, Figure 4-190). Table 3-14 lists the values.

Table 3-14. Primary impact indicators for long-term performance.[a]

	Draft EIS thermal load scenario[b]			S&ER flexible design operating mode	
Primary impact indicators	High	Intermediate	Low	Higher-temperature	Lower-temperature
10,000-year peak of the mean annual dose[c] (millirem/year)	0.22[d]	0.13[d]	0.059[d]	0 (zero)[d]	0 (zero)[d]
Peak of the mean annual dose (post-10,000 years)[c] (millirem/year)	260	170	160	120	120[e]
Time at peak[c] (years after closure)	340,000	800,000	800,000	550,000	550,000[e]

a. Values rounded to two significant figures.
b. Source: DOE 1999, Tables 5-6, 5-8, and 5-12.
c. Postclosure receptor at 20 kilometers (12 miles).
d. Does not include disruptive (igneous) events or human intrusion.
e. Assumed from higher-temperature case given that thermal differences effectively cease many years before first waste package failure.

The proposed standard of the Environmental Protection Agency (40 CFR Part 197; 64 *FR* 46976, August 27, 1999) would require DOE to look at a period as long as 10,000 years for meeting quantitative standards for protecting health and safety. The proposed standard also would require DOE to look farther out in time to see when the peak dose would occur, and how high it could be. Table 3-14 lists the peak of the mean annual dose out of 300 simulated dose histories for a 1-million-year period. The estimated mean annual dose would reach a peak of about 120 millirem per year [to the receptor 20 kilometers (12 miles) from the site] at about 550,000 years, and would decline thereafter for the current most reasonable modeling case (DOE 2001a, Figure 4-190).

3.3 Cumulative Impacts

Chapter 8 of the Draft EIS (DOE 1999) evaluated the environmental impacts of repository activities coupled with the impacts of other past, present, and reasonably foreseeable Federal, non-Federal, and private actions. These are referred to as cumulative impacts. Chapter 8 included a detailed analysis of nuclear material in excess of the Proposed Action quantities, referred to as Inventory Modules 1 and 2. The additional material would consist of additional spent nuclear fuel, high-level radioactive waste, and wastes not considered in the Nuclear Waste Policy Act, as amended (42 USC 10101 *et seq.*), but reasonably foreseeable as candidates for disposal in a geologic repository.

Changes in cumulative impacts associated with the S&ER flexible design would be proportional to the change between the Proposed Action in the Draft EIS and the impacts discussed in Chapter 3 of this Supplement. This relationship would be most noticeable in estimating the impacts from Inventory Modules 1 and 2. For example, a 20-percent increase over the Draft EIS low thermal load scenario of the Proposed Action by the S&ER flexible design lower-temperature repository operating mode would be likely to result in a 20-percent increase over the low thermal load scenario in that specific impact for the inventory modules. Other than the inventory modules, DOE expects cumulative impacts to be essentially the same as those presented in Chapter 8 of the Draft EIS.